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[54] RADIOISOTOPE HEAT SOURCE BOILER FOR POWER GENERATORS

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[51] **Int. Cl.** **G21c 15/18**

[58] **Field of Search** 176/57, 87, 26, 27; 126/344; 136/202; 204/193; 60/108; 122/32; 310/3

[56] **References Cited**

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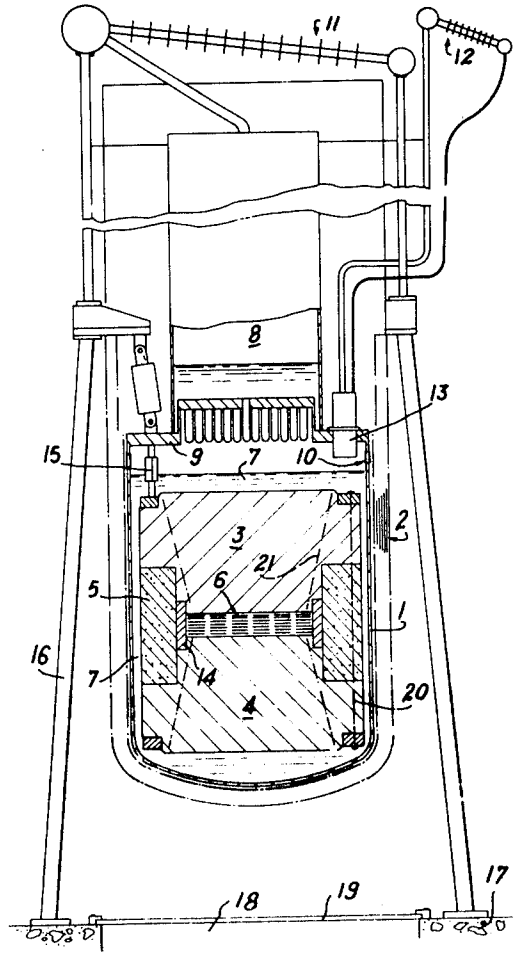
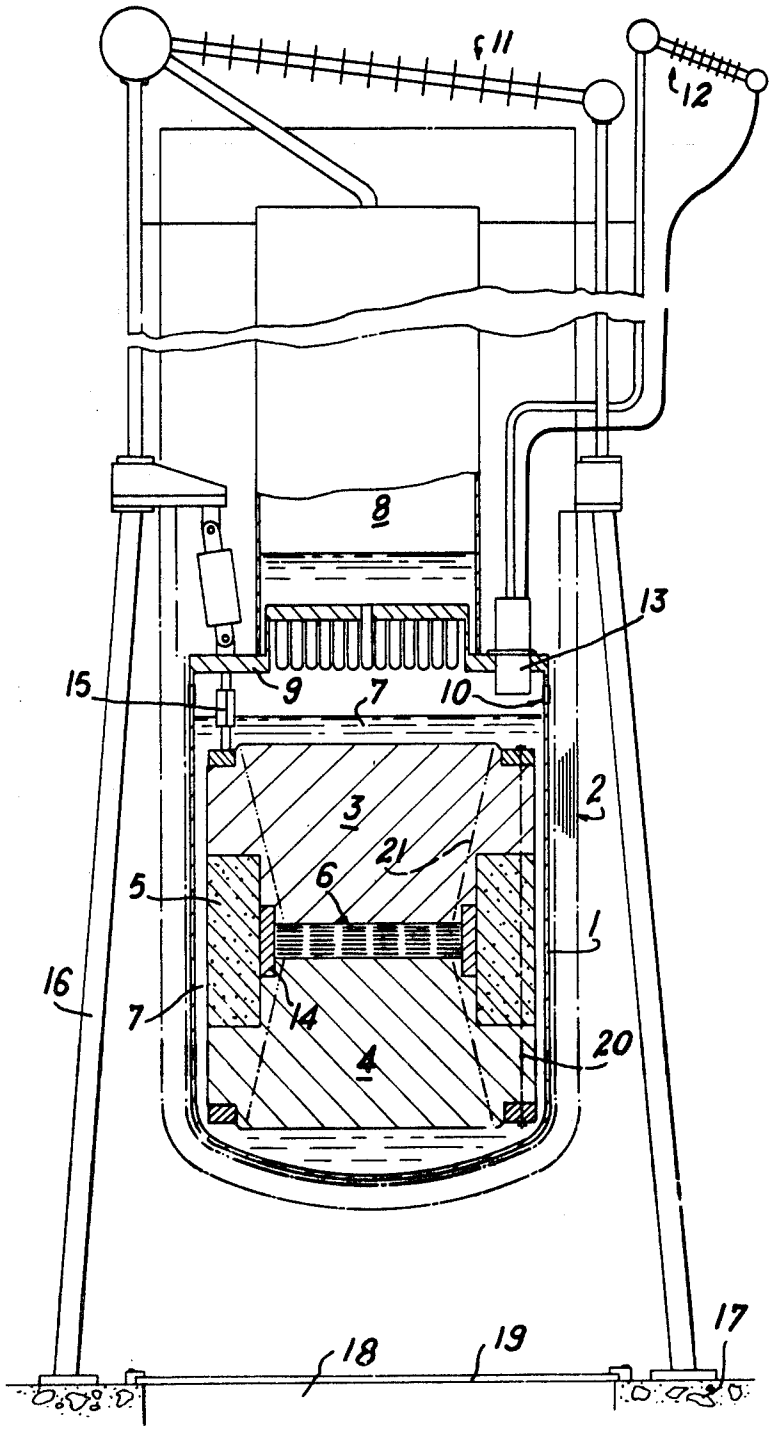
[57] **ABSTRACT**

The boiler essentially comprises a vessel of revolution having an external heat-insulating covering and a radioisotope source which is housed within the vessel. The source is constituted on the one hand by two blocks of revolution formed of material which is capable of providing a good biological shield. A peripheral recess is formed in each block in order to accommodate a tightly-fitting annular member, said member being constructed of material having a radioactive absorption coefficient which is higher than that of the blocks. The source is constituted on the other hand by a charge of radioelements formed by a series of clad radioactive plates arranged in stacks. The complete radioisotope source unit is immersed in a cooling liquid. The top end-wall of the boiler proper constitutes the hermetic cover of the vessel. A safety member which is welded to the upper block and to the cover ensures falling of the vessel and of the radioisotope source in the event of dangerous overheating.

10 Claims, 1 Drawing Figure

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RADIOISOTOPE HEAT SOURCE BOILER FOR POWER GENERATORS

This invention relates to a radioisotope heat source boiler for power generators and, in particular, for high-power electric generators.

Electric generators of the radioisotope source type can be divided according to their power ratings into microgenerators, medium-power generators and high-power generators.

In particular, a known type of high-power electric generator comprises a converter which operates on the Rankine cycle and is supplied by a boiler in which the fuel is a radioisotope source formed of cobalt-60 pellets which have a double coating and are disposed at the center of a spherical tungsten shield.

This invention relates to a boiler for power generators and in particular high-power electric generators, said boiler being intended to be associated with a converter. The boiler essentially comprises a vessel of revolution which is fabricated from stainless steel and provided with an external heat-insulating covering formed of a laminated structure of layers having low conductivity and reflecting layers, a radioisotope source housed within said vessel and constituted on the one hand by two blocks of revolution fabricated from a material which is capable of providing good biological protection and has good heat conductivity, said two blocks being placed at a small distance from each other within said vessel so that the axes of revolution thereof should coincide with the axis of said vessel and being each provided with a peripheral recess in which is tightly fitted an annular member formed of material having a radioactive absorption coefficient which is higher than that of said blocks and on the other hand by a charge of radioelements formed of a series of clad radioactive plates which are housed in the space between said blocks and have the shape of very flat discs whose end faces are oriented at right angles to the axis of revolution of said blocks, said plates being arranged in stacks and each stack being clamped between said blocks, the complete radioisotope source being immersed in an organic cooling liquid having a boiling point which is higher than 250°C, and a boiler proper whose top end-wall constitutes the hermetic cover of said vessel, a safety member which is fusible at a given temperature and welded to the upper block and to said cover being intended to ensure falling of said vessel and of said radioisotope source in the event of dangerous overheating of said source.

The laminated structure which forms the heat insulating covering of said vessel is composed, for example, of layers of glass wool and very thin aluminum sheets.

Advantageously, the two blocks of revolution are formed of copper and the annular member which is adapted to fit in the peripheral recesses of said blocks is formed of depleted uranium.

The plates which constitute the charge of radioelements are advantageously formed of cobalt-60 and the cans of said plates are formed of stainless steel.

The organic cooling liquid in which the radioisotope source unit is immersed is advantageously a diphenyl-diphenyloxide mixture in suitable proportions or alternatively liquid sodium or a liquid sodium-potassium mixture.

Further properties and advantages of the present invention will become apparent from the description which now follows below.

Reference will be made to the single accompanying FIGURE which shows by way of non-limitative example and in axial vertical cross-section a radioisotope source boiler according to the invention which is mounted on a power generator.

As appears from this figure, the boiler in accordance with the invention is essentially constituted by a vessel **1** of revolution having a heat-insulating covering in the form of a laminated structure **2**, a radioisotope source constituted on the one hand by two blocks **3** and **4** of copper (or tungsten) provided with peripheral recesses in which are fitted an annular member **5** of depleted uranium (or tungsten) and a copper ring **14** made up of two sections and on the other hand by a charge of radioelements formed of a series of small plates **6** of cobalt-60 or strontium, for example, said plates being clad with stainless steel and arranged in stacks which are clamped between the blocks **3** and **4**. The entire radioisotope source unit is immersed in a cooling liquid **7** such as diphenyl-diphenyloxide, for example. The boiler **8** proper has a top end-wall **9** which serves as a hermetic cover for the vessel **1**. A safety plug **10** which is designed to melt at approximately 320°C is welded to the vessel **1** and to the cover **9** of this latter and a safety member **15** which is designed to melt in the vicinity of 400°C is welded to the block **3** and to the cover **9**.

The boiler unit according to the invention as hereinabove described and as shown in the figure is mounted beneath a power generator such as a high-power electric generator which does not specifically form part of the invention.

Said electric generator which is shown very diagrammatically in the drawing comprises a converter formed of two stages containing different organic fluids which each flow in a Rankine cycle.

The boiler of the first stage of said converter (namely the stage which has the highest temperature) is the above-mentioned boiler **8**. The condenser of said boiler (not shown) constitutes the boiler of the second stage. The condenser of said second stage (reference **11**) is self-cooled by means of the surrounding air.

Provision is made for an emergency condenser (reference **12**) of the self-cooled type which can be put into communication at **13** with the top portion of the vessel **1** in the event of an abnormal temperature rise.

The complete converter unit is supported on the ground by means of standards **16** which are embedded in concrete blocks **17**, provision being made beneath the boiler in accordance with the invention for a pit **18** which is covered with a glass plate **19**. Finally, the two copper blocks **3** and **4**, the annular member **5** and the ring **14** are maintained clamped together by means of tie-rods **20**.

The operation of the radioisotope source boiler in accordance with the invention takes place as follows. By reason of the fact that the small plates **6** are very flat discs and that the blocks **3** and **4** have substantially higher conductivity than the annular member **5**, practically the entire quantity of heat given off by said small plates is transmitted by conduction into the frusto-conical portion of the copper block **3** (as delimited in the figure by the chain-dotted line **21**), then by boiling of the organic liquid **7** and then by condensation on the top end-wall **9** of the boiler **8** proper.

Only an extremely small proportion of the heat generated by the plates is transmitted through the annular member **5** of depleted uranium (or tungsten). Baffles (not shown in the figure) are provided between the blocks **3** and **4** and the member **5** in order to leave a clearance which does not present any hazard; by welding of lips, the combined assembly of these three elements is made impervious to any penetration of organic liquid **7** into the space which contains the charge of radioelements.

A number of different safety systems are provided in order to guard against any danger of an excessive temperature rise:

a. In the event of outage of the converter and a temperature rise to 280°C, for example, the emergency condenser **12** is put into communication at **13** with the top portion of the vessel **1**. Condensation of the vapor which is produced by the organic liquid **7** is then carried out in said emergency condenser.

b. If the temperature attains 320°C, for example, the plug **10** melts and atmospheric pressure is then established within the vessel **1**. The surrounding air ensures sufficient cooling by reason of the fact that the maximum permissible temperature of the small plates of cobalt-60 (reference 6) is of the order of 700°C.

c. In the event of total failure of the converter, the ultimate emergency measure consists in detaching the complete assembly of vessel **1** and heat insulation from the cover **9**. To this end, if the temperature attains 400°C, for example, the

safety member **15** melts, with the result that the block **3** and consequently the whole radioisotope source unit is detached from the cover **9** and falls into the pit **18**.

The radioisotope source boiler in accordance with the invention must be indestructible at the time of handling operations to which it may be subjected. To this end, impact resistance of the boiler in the event of any accident condition arising during transportation is provided by a protective cover or shell having an open structure which may be formed of expanded polystyrene, for example.

As is readily apparent, this invention has been described in the foregoing by way of explanation but not in any limiting sense and any detail modifications may accordingly be contemplated without thereby departing from its scope.

What we claim is :

1. A boiler for power generators and in particular for high-power electric generators, wherein said boiler comprises a vessel of revolution which is fabricated from stainless steel and provided with an external heat-insulating covering formed of a laminated structure of layers having low conductivity and reflecting layers, a radioisotope source housed within said vessel and constituted on the one hand by two blocks of revolution fabricated from a material which is capable of providing good biological protection and has good heat conductivity, said two blocks being placed at a small distance from each other within said vessel so that the axes of revolution thereof should coincide with the axis of said vessel and being each provided with a peripheral recess in which is tightly fitted an annular member formed of material having a radioactive absorption coefficient which is higher than that of said blocks and on the other hand by a charge of radioelements formed of a series of clad radioactive plates which are housed in the space between said blocks and have the shape of very flat discs whose end faces are oriented at right angles to the axis of revolution of said blocks, said plates being arranged in stacks and each stack being clamped between said blocks, the complete radioisotope source being immersed in an organic cooling liquid having a boiling point which is higher than 250°C, and a boiler proper whose top end-wall constitutes the hermetic cover of said vessel, a safety member which is fusible at a given temperature and welded to the upper block and to said cover being intended to ensure falling of said vessel and of said radioisotope source in the event of dangerous overheating of said source.

2. A boiler in accordance with claim **1**, wherein said laminated structure is composed of layers of glass wool and very thin aluminum sheets.

3. A boiler in accordance with claim **1**, wherein the two blocks of revolution are formed of copper.

4. A boiler in accordance with claim **1**, wherein the two blocks of revolution are formed of tungsten.

5. A boiler in accordance with claim **1**, wherein said annular member is formed of depleted uranium.

6. A boiler in accordance with claim **1**, wherein said annular member is formed of tungsten.

7. A boiler in accordance with claim **1**, wherein said plates are formed of cobalt-60.

8. A boiler in accordance with claim **1**, wherein said plates are formed of strontium-90.

9. A boiler in accordance with claim **1**, wherein said cooling liquid is a diphenyl-diphenyloxide mixture.

10. A boiler in accordance with claim **1**, wherein said cooling liquid is liquid sodium or a liquid sodium-potassium mixture.

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